COMPARISON OF SHEAR & TENSILE BOND STRENGTH OF BRACKETS BONDED WITH A CONVENTIONAL (2 STEP) AND A SELF- ETCH (ALL IN ONE) BONDING SYSTEMS -AN IN VITRO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"COMPARISON OF SHEAR & TENSILE BOND STRENGTH OF BRACKETS BONDED WITH A CONVENTIONAL (2 STEP) AND A SELF- ETCH (ALL IN ONE) BONDING SYSTEMS -AN IN VITRO STUDY"** is a bonafide research of work done by **Dr. B.AKILANANTH.** Under my guidance during his postgraduate study period between 2009-2012.

This dissertation is submitted to THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY, in partial fulfilment for the degree of Master of Dental Surgery in Branch V-Orthodontics.

It has not been submitted (partially or fully)for the award of any other degree or diploma.

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CONTENTS

Orthodontic metal bands made of platinum were used in 1870s by W.E.Magill,[7] (which has been used centuries ago by the Phoenicians, and was later reintroduced by various men like C.A Harris) were cemented to the teeth by oxychloride of zinc cement and have been in existence for more than 100 years. The introduction of acid etching technique by Buonocore in 1955[15] and the development of orthodontic resins (Diglycidyl ether of Bisphenol-A, with a polyamide curing agent) by Bowen [12], has replaced the banding with bonding, making a new era in orthodontic history. This offered exciting possibilities of a more aesthetic appearance for the patient with other advantages of having no band spaces to close after treatment, less gingival irritation, increased ease of plaque removal etc.

Ever since the inception of bonding to orthodontics, the materials used for bonding have undergone considerable improvement from time to time. Present day adhesives bonding systems claim superior bonding characteristics, even in difficult to isolate and hard to reach areas. The future of bonding is promising as these material developments in term of adhesive bond strength, brackets design, and technical details are continually occurring at a rapid rate.

In 1955 Bunocore laid the foundation for adhesive restoration and preventive dentistry by introducing etching enamel which renders it more receptive to adhesion and advocated use of 85% phosphoric acid for 30 seconds. Subsequently, Gwinnett, Matsui and Bunocore[26] Suggested that formation of resin tag from the adhesive was the primary mechanism of attachment. Etching removes about 10 micron of enamel and creates porous layer that ranges from 5 to 10 micron depth.

Silverstone reported that phosphoric acid concentrations between 30% and 40% provide enamel surface that have the most retentive appearance and as a result of these studies most of the commercial etchants now available are with 37% concentration.

One of the potential disadvantages of etching with phosphoric acid is that the acid causes demineralization of the most superficial layer. To control excessive enamel loss, maleic and polyacrylic acids have been used as alternatives for phosphoric acid. The use of these acids were found to result in a reduction in bond strength[69]

Conventional resin composites require the use of 3 different agents (enamel conditioner, primer, and adhesive resin) to bond orthodontic brackets to enamel. Because of their hydrophobic properties, these products require completely dry and isolated fields to obtain clinically acceptable bond strength.

However, a variety of clinical conditions do not permit ideal isolation. Moisture contamination is considered the most common reason for bond failure. When etched enamel becomes wet, most of the pores become plugged, and resin penetration is impaired[65,] resulting in resin tags of insufficient number and length. Even momentary saliva contamination adversely affects the bond, because saliva deposits an organic adhesive coating in the first few seconds of exposure that is resistant to washing. Thus, it would be advantageous to be able to bond to enamel in a wet environment, particularly in hard-to-reach areas, such as around second molars or partially erupted and impacted teeth.

To address the problem of contamination, manufacturers introduced hydrophilic bonding materials that promised successful bonding to a moisture-contaminated enamel surface. Some hydrophilic enamel primers for orthodontic treatment are formulated with alcohol or acetone to displace moisture from the isolated enamel surface.Transbond Moisture Insensitive Primer (MIP; 3M Unitek, Monrovia, Calif) contains a hydrophilic primer dissolved in acetone and is recommended for use on dry or wet etched enamel with either self- or light-cured bonding agents.

More recently, newly formulated self-etching primers were developed to combine conditioning and priming agents into a single acidic primer with simultaneous use on enamel and dentin, thus eliminating the need for separate etching, rinsing, and drying. This type of product would have the advantage of a faster and simplified application technique and allow effective conditioning and priming of enamel and dentin in 1 step, without sacrificing adequate bond strength.[17]

These self-etch primers help the clinician save time, reduce cross-contamination, and reduce wastage. Because they are hydrophilic, it is logical to presume that they may be effective in situations with minimal moisture contamination. Combining conditioning and priming agents into a single treatment step results in reduced time and improved cost-effectiveness for the clinician and indirectly for the patient.

These relatively new systems were used originally on dentin. Essentially, the acidic part of the primer dissolves the smear layer and incorporates it into the mixture. Acidic primer solutions also demineralizes the dentin and encapsulate the collagen fibers and hydroxyapatite crystals. This simultaneous conditioning and priming allows penetration of the monomer into the dentin[45]. The adhesive resin component will then diffuse into the primed dentin, producing a ''hybrid layer.'' These new systems were found also to be effective when bonding to enamel.

Xeno IV[45] (Dentsply Caulk, Milford, Massachusetto, USA) is a self- etching adhesive system that is said to demonstrate high performance in terms of self-etching technology by providing a bond to enamel and dentine comparable with those of conventional adhesive systems with phosphoric acid conditioning.

Mathews Melo Pithon et al did a study on bond strength of Xeno IV self-etching bonding agent on bovine lower incisors and concluded that Xeno IV was able to bond orthodontic brackets in association with Transbond XT composite[41].

Combining the use of Xeno IV with Transbond XT adhesive reduces the number of steps and significantly reduces chair side time. However achieving an effective bonding with adequate bond strength is the main target .Therefore the aim of this study was to compare the shear and tensile bond strength of Xeno IV with Transbond XT adhesive resin to the conventional 2 step(acid etching followed by priming and bonding) bonding technique which has a proven track record of consistently providing bond strengths exceeding the minimum required bond strength.

Buonocore (1955)[24] presented a simple method of increasing the adhesion of acrylic filling materials to enamel surface by chemical treatment. Two methods were used for treating the enamel surface. 1) 50% dilution of commercial phosphomolybdate reagent containing sodium tungstate in conjunction with a 10% oxalic acid solution. 2) 85% phosphoric acid for 30 seconds. The author concluded that the phosphoric acid treatment seems to give better results and was simpler to use and these findings opened a new approach to the problem of obtaining adhesion to the tooth surfaces.

Saddler (1958)[70]investigated commercial adhesives (two metal adhesives and two general adhesives) to determine the possibility of bonding metal attachments directly to the teeth and eliminating the bands completely. The author concluded that none of the adhesives at that time were capable of bonding metal attachments to the teeth with a stability required for clinical orthodontics.

Newman (1965)[55] introduced novel concept of epoxy adhesive formula to bond plastic orthodontic attachments to tooth surfaces which was more esthetic and hygienic as an alternative to the cementation of metal bands. The enamel structure was altered with 40% phosphoric acid for 60 seconds. The epoxy adhesives were reaction products of bisphenol A and epichlorhydrin to which 2 grams of polyamide resin (curing agent) was added. This joint had good shear bond strength and rigidity, excellent wetting properties with minimal irritation.

The only disadvantage was that gelling occurred in 15-30 minutes and complete curing took 4 days. According to the author the orthodontic force applied to the brackets is approximately 1MPa. He stated that a load of approximately 3 MPa is the maximum which probably occurs under clinical conditions.

Bowen et al (1965)[12] advocated the use of Adhesion Booster**,** a tooth surface primer to increase bond strength of composite resin to tooth surfaces. The expression of "adhesion booster" was used in connection with certain molecules such as NPG-GMA (N-phenylglycine and glycidyl methacrylate). This was also referred to as coupling agent. This meant that one end of this molecule bonded to dentin which was hydrophilic in nature and the other end polymerized to composite resin. This characteristic should reduce interfacial porosity and therefore increase adhesion. On the basis of these concepts, various orthodontic adhesives were introduced to improve bond strength and interfacial integrity.

Mulholland (1968)[49] explored the effects of acid pre treatment solutions with varying pH on direct bonding of brackets to enamel surface. Four acid solutions were used, 2-monovalent (Hydrofluoric and Hydrochloric) and 2-polyvalent (Phosphoric acid and Aspartic). They concluded that hydrofluoric acid lead to significant increase in bond strength at pH 4 when compared with HCl at same Ph because of increased wettability. Etching effect is indirectly proportional to pH. More the concentration of the solution more the ions aggregates which inhibits wettability and leads to the formation of voids. These voids decreased the bond strength. Phosphoric acid increases the wettability with water drops. Polyvalent acids at pH 2.6 dissociate and acts like monovalent acids.

Newman (1968)[56] reported on acrylic adhesives for bonding attachments to tooth surface by pre treatment with phosphoric acid and minimum shrinkage of adhesive (Homo and

Co-polymers of methyl methacrylate) during set as low level as possible, without reducing the mechanical properties of set adhesive, so that bond strength was not impaired. Further improvement in joint strength was noted when powdered fused quartz was added to the adhesive as filler and the results also suggested that breakdown of adhesive joints by water was less significant for stronger adhesive bonds.

Newman (1969)[54] described some of the laboratory and clinical findings encountered in solving a method for bonding plastic brackets to toothsurfaces. The author dealt with many parameters including adhesive system and concluded that acrylic adhesives were superior to epoxy adhesives in terms of bond strength (monomers tend to penetrate and polymerize into microscopic pores of etched enamel and enhancing mechanical retention), minimal shrinkage, flexibility of bond strength and no allergic dermatitis. The only disadvantage noticed with this system was delayed setting time (5 minutes) which tended the brackets to float on the teeth until final setting occurred.

Retief et al (1970)[67] introduced epoxy resin with different formulation for bonding metal brackets directly to enamel surfaces. An optimal preheat schedule was determined for this formulation. The flow of curing resin was reduced by thixotrophic agent, Aerosil. The authors also attempted to improve the rate of curing by hot compressed air, infrared heating and conduction heating by means of electric current. The results of the clinical trial showed 20% bracket failure rates and the possible reasons were inadequate washing of etched surfaces after phosphoric acid treatment and shelf life of the reagents were not taken into consideration.

Buonocore (1970) [14] developed adhesive sealing of pits and fissures for caries prevention, with use of ultraviolet light. Major ingredients of the adhesive were[3] parts by weight of reaction product of bisphenol A and glycidyl methacrylate and 1 part by weight of methyl methacrylate monomer. To obtain an ultra violet sensitive mixture, 2% of benzoin methyl ether was added just before use to the adhesive. The author also emphasized this technique for important potential applications in orthodontics for cementation of plastic orthodontic brackets.

Newman (1971) [53] studied the effects of adhesives on tooth surfaces and Concluded that surface pre treatment with solution containing 50% phosphoric acid, 5% zinc oxide and 1% sodium monoflurophosphate creates surface roughness by opening of microscopic pores and enhances adhesion. SEM photomicrographs revealed removal of adhesive and repumicing of bonded surface restore the tooth surface to its original pumiced appearance.

Miura et al (1971) [48] described a new direct chemical bonding system for plastic brackets. This consisted of pre treatment with phosphoric acid and methacryloxyprophy tri-methoxysilane and subsequent application of self curing acrylic resin as the adhesive, with tri-*n*-butyl borane as catalyst. The bonding by this method between plastic brackets and enamel surface was stable and effective and there was only a minute decrease in bond strength, even after long term immersion in water. Electron microscopy study revealed no hazardous secondary effects of pre treatment procedures on the tooth surface. Shear bond strength of 5.1 MPa was obtained which yielded clinically satisfactory results over a two year period.

Cohl et al (1972)[21] tested the usefulness of ultraviolet adhesive bracketing system under active orthodontic conditions. The bonding adhesive was the type developed by Buonocore. The author concluded that the ultraviolet bonding system had clinical orthodontic potential because of adequate time for individual bracket placement but only 20 seconds for polymerization and no time delayed in applying orthodontic forces to the brackets. Brackets failure rate was 13% with mean strength of 57.7 kg per square centimeter. The bracket adhesive interface and the bracket itself were found to be the weakest link in the bonding system.

Silverman et al (1972 and 1974)[73] reported a universal bonding system (Caulk Nuvalite) for indirect positioning and bonding of both metal and plastic brackets. This procedure was thought to be first to place metal brackets on teeth for comprehensive treatment procedures. The bonding adhesive was the type developed by Buonocore as fissure sealant. Synthetic calcium hydroxyappetite and calcium fluoride were added to the adhesive. The technique described enabled the orthodontist to place all brackets precisely in one arch in matter of 10-15 minutes with the help of vanguard tray including the pretreatment step with phosphoric acid group. Previous adhesives required a hurried approach to place the brackets due to rapid setting time.

Daft et al (1974)[23] **investigated** three types of commercially available direct bonding systems in conventional clinical situations. Direction adhesive, Unitek adhesive and Nuva seal in conjunction with GAC bracket bond and concluded that the results except for the Nuva seal-GAC bracket bond had somewhat high failure rate ranging from 25-100% and it was also noticed that the critical area of failure was at the adhesive enamel interface.

Lee et al (1974) [41]evaluated in vitro and in vivo direct-bonding orthodontic bracket systems. The properties of most importance from the standpoint of clinical performance were compared for three systems, a first-generation methyl methacrylate-based system, a second-generation two-step system, and Genie to represent the third-generation. For all adhesive systems, the 24-hour adhesive strength, in the range of 7 to 14 pounds, exceeded the threshold distortion limits of the polycarbonate. The range of adhesive strengths was similar for bovine and human enamels. They concluded that until plastic brackets can be made stronger, this test is feasible only by substituting plastic discs or cylinders for the brackets.

Retief (1975)[66] studied the effect of various concentrations of phosphoric acid on the bond strength of an epoxy adhesive formulation developed for direct bonding of brackets and concluded that 50% phosphoric acid solution as a conditioning agent must be advocated prior to the use of epoxy adhesive formulation. The author also suggested that the optimal phosphoric acid concentration should be determined for each adhesive system.

Gorelik (1977)[34] presented an effective procedure for bonding metal brackets to enamel by using self polymerizing sealant-composite (2 part system consisting of resin [sealant] packaged as 2 separate liquids and composite packaged as 2 separate pastes). The authors also emphasized on difficulty of debonding where adhesives remain in bulk on the tooth surfaces. Removal of remaining material is time consuming, tedious and uncomfortable. Data also presented that in terms of bond strength it did not seem to matter clinically if 37% for 60-90 seconds or instead 50%orthophosphoric acid in thixotrophic or liquid form for 2- 2½ minutes was used.

Newburg and Pameijer (1978)[51] studied the bonding of composite resins to porcelain with silane solution and concluded that a reliable bond was possible for various applications including bracket placement.

Zachrisson (1979)[84] assessed the polymerization in thin films on tooth surfaces for 4 conventional bonding pit and fissure sealants and one acetone containing sealant and concluded that all 4 conventional sealants failed to produce a thin protective film to cover the entire etched surface. This was mainly due to nonpolymerization caused by oxygen inhibition and to sealant flow before setting. The chemical analysis indicated a large amount of unreacted methacrylate groups where these sealants had polymerized. In contrast, the acetone containing sealant polymerized to a thin film with less remaining methacrylate groups. The author also emphasized the need for improved sealants for orthodontic bonding purposes.

Beech and Jalaly (1981)[6] evaluated clinical and laboratory findings of some orthodontic bonding systems (epoxy resins, plycarboxylate cements based on methacrylate, with and without filler) used in conjunction with acid etching and concluded that high bond strengths adhesives (highly filled acrylic diacrylate adhesives) were undesirable because of more complexity in terms of isolation and steps involved in preparing the tooth surface and difficulty encountered while debonding and risk of enamel loss and damage. The use of a dilute mix of self curing acrylic and a primer to treat plastic brackets gave an excellent bond (clinically acceptable) with dimethacrylate adhesives in terms of simplicity of technique, cost, setting time, ease of bracket placement and removal.

Newman et al (1984)[57] compared in vitro, the shearing strengths of the brackets bonded directly to Isosit (composite resin type) and porcelain with and without a silane coupling agent (gamma methacryloxypropyltrimethoxysilane). A normal acid etch procedure to enamel served as a comparison. The authors concluded that silane enhance the composite bonding of brackets to porcelain restorations. This bond was still not clinically significant and required additional research. However orthodontic brackets can be bonded to the Isosit as effectively as they can be bonded to acid etched enamel by composite resin bonding system. Silane does not significantly affect the bond strength.

O'Brien et al (1989)[60] compared the clinical performance of visible light cured material and chemically cured adhesive and the results indicated overall clinical failure rates of 6% for a chemically cured adhesive. The authors concluded that visible light cured adhesive can be a satisfactory alternative to conventional chemically cured material and also suggested that with the use of visible light cured adhesive, maximum polymerization of the adhesive system was achieved after exposure to the light source, it was therefore not necessary to delay archwire placement as in the case of chemically cured in which archwires could not be placed until complete polymerization took place.

Coreil et al (1990)[22] evaluated the shear bond strength of then newly introduced[3] types of bonding systems (Saga sealant, maximum Cure and Scotchbond-2) which contained solvents and was claimed to improve the polymerization of unfilled resin primers and may increase the bond strength. These bonding systems were compared with conventional orthodontic bonding system (Concise). The authors concluded that addition of solvents did not significantly increase the bond strength when compared with the conventional bonding system. The enamel bond strength achieved with Scotchbond 2 was not as good as those achieved with other systems. This bonding agent was designed to improve bonding to dentin, and it would appear that there is no advantage to its use when only enamel bonding is involved

Paul Surmont et al (1992)[63] evaluated shear bond strength of orthodontic brackets between five bonding systems related to different etching times .There was no significant difference in shear bond strength between 15 and 60 seconds enamel etching before bond application

Newman et al (1995)[52] proposed different techniques (sandblasting, sandblasting with silanating, Rocatec system, Silicoating and adhesion promoters) to enhance the bond strength of metal brackets and concluded that adhesion promoters (Megabond) and Silicoating (Kulzer) resulted in favorable increased bond strength upto 13.3 Mpa. Adhesion promoters were indicated in non-complaint patients, fluorosed and hypo calcified tooth enamel. The chemical composition of Megabond is M-1: NTG-GMA (magnesium salt of N-tolyglycineglycidyl methacrylate) in acetone and inhibitors, M-2: PMGDM in acetone and M-3: Mono and difunctional monomers and oligomers. M1 and M2 were used primarily for tooth enamel structure and M2 and M3 were used for coating mesh metal brackets.

Edward Swift jr 1995[26] Acid etching removes about 10 microns of enamelsurface and creates a porous layer ranging from 5 to 10 micron deep. When a low viscosity resin is applied it flows into the microporosites and channels of this layer and polymerizes to form a micromechanical bond with the enamel.wetting also increases the wettabily and surface area of the enamel substrate

Olsen et al (1997)[61] compared the effects on bond strength and bracket failure location of two adhesives (System 1+ and Scotchbond Multipurpose) and two enamel conditioners (37% phosphoric acid and 10% maleic acid). The results indicated that there was no significant difference in the bond strength among any of the 4 groups and concluded that the use of Scotchbond Multipurpose and/or maleic acid can be used as an alternative method for bonding brackets. However the use of maleic acid resulted in an unfavorable bond failure location (enamel-adhesive interface).

T. Frost, D.D.S 1997[31] compared, a standard-sized 11-mm light guide and a 19-mm elliptical extra broad light guide,the latter designed to allow simultaneously curing of two adjacent brackets and the results showed no statistically significant differences between the standard and elliptical light guides regarding tensile bond strength, or bracket failure frequency. However, with the larger light guide size a significantly shorter total bonding time for each patient was required. It is therefore concluded that the elliptical light guide in combination with a light transmitting unit of sufficient quality gave a similar bonding result as the standard light guide, offering the clinician a reduction in chair side time during the bonding procedure

Bishara et al (1998)[11] studied the effects on the shear bond strength and the bracket adhesive failure mode when an acidic primer (contains both acid [Phenyl-P] and the primer [Hema and dimethacrylate]) and other enamel etchants were used to condition the enamel surface before bonding. It was believed that enamel conditioners, such as maleic acid, and acidic primers that contain Phenyl-P may be beneficial in achieving clinically useful bond strength while decreasing the depth of enamel dissolution. They concluded that use of acidic primers to bond orthodontic brackets to the enamel surface provided clinically acceptable shear bond strength when used with highly filled adhesive [Bis-GMA]. The bond strength was comparable to those obtained when the enamel was conditioned with either 37% phosphoric acid or 10% maleic acid. The ARI results showed that there was a tendency to have less residual adhesive remaining on the tooth when an acid primer was used than phosphoric and maleic acid groups.

Hugo R. Armas Galindo (1998)[35] evaluated and compared the rate of success and/or failure between a visible light-cured bonding material and a chemically cured bonding material.Hisfindings suggested that both the visible light-cured bonding material and chemically cured bonding material methods were found to be clinically acceptable with a failure rate of 11.3% for the visible light-cured composite and12% for chemically cured composite. There was no statistically significant difference in the failure rates when comparing the two systems. There were statistically significantly more failures in the posterior segments of the dental arches than in the anterior segments

Canay et al (2000)[20] compared the effect of conventional acid etch with enamel air abrasion preparation technique on the retention of bonded metallic orthodontic brackets and concluded that sandblasting should be followed by acid etching group to produce enamel surfaces with significantly higher bond strength. Enamel surface preparation using sandblasting alone resulted in significantly lower bond strength.

Brosnihan and Safranek (2000)[13] demonstrated the technique and uses ofPROMPT L-POP system (First 6th generation bonding system released in the market). This unit dose system with etchant, primer, adhesive and microbrush were sealed in triple lollipop shape aluminium foil package and sufficient to bond 4-5 teeth making it especially convenient for rebonding brackets and for limited treatment bonding. Acid etching, rinsing, priming,application of adhesive are thus combined in one step ultimately reducing the number of steps and saving chair side time. The first two chambers contained methacrylated phosphates, a fluoride complex initiators, and stabilizers in an aqueous solution. The fluid is then expelled into the third bubble chamber that houses the applicator tip. At this stage the moist tip containing adhesive was rubbed onto the enamel surface for 15 seconds and the brackets were positioned onto the enamel surfaces and light cured for 10 seconds. PROMPT L-POP system was found to be incompatible with self curing resin composite materials.

Kugel and Ferrari (2000) [39] and **Freedman and Leinfelder (2003)** [30] reviewed the evolution of bonding systems and mentioned the milestones of the development of adhesives. We have summarized their literature in the following chart.

Bonding Generation	Contributors	Components	Characteristics	Chemistry	Bond Strength to Dentin	Trade Names
1st	Michael Gabriel Buonocore (1955) Rafael L.Bowen(1965)	1	**Very weak bond to dentin**	Etching of enamel by phosphoric acid and bonding to acrylic resin. This concept was considered as milestone for "adhesive dentistry". Development of compositeand Introduction of NPG – GMA to facilitate chelationwith surface calcium.	2 MPa	Cervident , Cosmic Bond
2nd	Rafael L.Bowen(1965)	2	Weak adhesives requiring retentive preps Prone to water degradation	Introduction of bis-GMA and HEMA molecule.	2-8 MPa	BondLite Scotchbond Dentin Adhesit
3rd	Nobuo Nakabayashi and Takeyama (1978)	2-3	2 component primer and adhesive system Bonding to metals Reduced sensitivity	Introduction of 4 – META and MMA / TBB resin.	8–15 MPa	PrismaUniversal Bond, Scotchbond II. Tenure, Gluma
4th	Takao Fusayama (1979) Nobuo Nakabayashi (1982) Erickson and Van Meerbeek (1992) J. Kanca (1992)	2-5	Hybridization, total etch, Little sensitivity	Introduction of total etchtechnique. Proposed the concept of resinreinforced hybrid layer. Concept of chemical union between organic and inorganic components of dentin. Moist bonding technique	17-25 MPa	All Bond II, Pro Bond, scotchbond MP, Bond It, Syntac
5th	Watanabe and Nakabayashi (1993)	1	Sigle component, moist bonding, hybridization, No mixing, Little sensitivity	Developed the self etching primer containing aqueous solution 20% of phenyl – P	20-24 MPa	Gluma comfort Bond, Prime and Bond NT, Single Bond , Excite , One step Bond 1
6th	Stephen M. Y Wei (2000) Imazato (2001) Kugel and Ferrari(2000)	2-3	Multi component, Multi step, self etching, Self priming, Hybridization, very little sensitivity.	One coat one bond and one cure technology. Introduction of antibacterial monomer MDPB in bonding.	18 – 23 MPa	Prompt-L – Prop, SE Bond, Liner Bond II
7th		1	Single component, desensitizing, self etching, self priming, no mixing, moisture independent, bonds to metal, very little – no sensitivity.		18-25 MPa	i BOND

The authors concluded that the 4^{th}, 5^{th} and 6^{th} generation bonding mechanism is achieved with hybrid layer and resin tag formation and could be greater than the forces of polymerization contraction. The ideal bonding system should be biocompatible, bond differently to enamel and dentin, sufficient strength to resist failure as a result of forces, mechanical properties close to those of tooth structure, resistant degradation in the oral environment and easy to use for clinician. Although important improvements had been made in the last 30 years, the requirements of ideal bonding system are quite similar to those indicated by Buonocore.

Dale Anne Featheringham, 2001[24] Investigated the bonding characteristics and polymerization shrinkage of orthodonticadhesives polymerized by exposure to either one of the following three curing light system and a variety of curing time. An argon laser (CureStar, Lares Research, Chico, Calif) at 4, 6, 8, or 10 seconds, a plasma arc curing unit (PAC Light, American Dental Technologies, Southfield, Mich) at 2, 4, 6, or 8 seconds and a conventional halogen light (Optilux XT, 3M Unitek) at 40 seconds.

The results were significant differences between the mean shear bond strengths were found for the visible light-curing systems and the adhesive materials at various time intervals. The mean shear bond strengths obtained with Transbond XT composite resin (TB) were significantly greater than those obtained with Fuji Ortho LC resin-modified glass ionomer (FO) at all time intervals except when curing with the plasma arc for 2 seconds. With TB, plasma arc curing at 4 seconds resulted in significantly higher mean shear bond strengths than curing with the plasma arc at 2 seconds or the argon laser at 4 seconds; argon laser curing at 8 seconds showed significantly higher mean shear bond strengths than it did at 4 seconds. With FO, no significant differences in mean shear bond strengths were found with plasma arc curing at 2, 4, 6, or 8 seconds; argon laser curing at 4 seconds resulted in mean shear bond strengths that were significantly lower than when curing for 6, 8, or l0 seconds. Analysis of bond failure location data with a categorical modeling procedure showed significant differences between adhesives but not between different curing lights. Therefore, the data from the 3 curing light groups for each adhesive were pooled for statistical analysis. Brackets bonded with TB produced significantly more cohesive failures, while those bonded with FO produced significantly more adhesive failures.

Miller (2001)[47] evaluated laboratory and clinical findings of Transbond plus Self-etching primer (identical to PROMPT L-POP system). This unit dose system was designed for bonding an entire dental arch and the chemistry of Transbond plus Self- etching primer is similar to that of phosphoric acid, with two primer chains that form a solid primer matrix upon curing. The liquid begins to etch the enamel as soon as it is applied, but changes to a primer once the two hydroxide chains are converted and hydrogen is released. Since no etchant remains on the enamel therinsing step was eliminated. Because the monomers that cause the etching are also responsible for bonding, the depth of penetration of monomers to be polymerized is exactly the same as the depth of demineralization, resulting in a complete hybrid layer resulting in superior bond strength. The clinical results were found to be satisfactory and worked well in difficult wet fields (impacted canines), fixed retainers and in indirect bonding and the bracket failure rates were also proved to be less.

Ram Kumar Grandhi 2001[65] In dry conditions with its conventional primer, the shear bond strength of Transbond XT was 11.06 MPa.With MIP in dry conditions, the shear bond strength decreased to 10.14 MPa (not significant after correction for multiple testing). However, MIP in combination with Transbond XT produced acceptable bond strengths in the presence of a thin film of water or saliva (9.69 MPa and 8.90 MPa, respectively; compared with dry enamel, *P* = .25 and .002 respectively).Each had a probability value of less than .001 for comparison with the conventional primer under the same testing conditions. There was little difference between the wet with water and wet with saliva groups

Bishra et al (2002) [9] in a study assessed the effect of saliva contamination on the shear bond strength of orthodontic brackets, at various stages of the bonding procedure using a new self-etch primer.He concluded that by reducing the number of steps during bonding orthodontic brackets to the teeth, clinicians are able to save time as well as reduce the potential for error and contamination during the bonding procedure. His findings indicated that the new acid-etch primer can maintain adequate shear bond strength if salivary contamination occurs either before or after the application of the primer. On the other hand, the combined contamination both before and after the application of the primer significantly reduced the mean shear bond strength by 75%.The present results indicated that the newly introduced self-etch primers, containing both the enamel etchant and primer have the potential to be successfully used in bonding orthodontic brackets even after light salivary contamination.

Aljubouri, Millet and Glimour (2003) [2] compared the mean bonding time and mean shear bond strength of stainless steel brackets micro etched base bonded with a light cured composite using SEP (self etching primer) and a conventional two stage etch and prime system. The authors concluded that the SEP significantly reduced bracket bonding time. The mean shear bond strength of the brackets bonded with SEP was significantly less than those bonded with a conventional two stage etch and prime system.

Buyukyilmaz et al (2003)[17] studied to determine the effects of using three self etching primers on the shear bond strength [SBS] of orthodontic brackets and on the bracket/adhesive failure mode and concluded that highest SBS was found to be in Transbond Plus group [TBP] than that found in Clearfil SE Bond [CSE], Etch and Prime group [EP3] and conventional acid etching groups. Clearfil SE Bond produced SBS that were comparable to those produced by acid etching. The use of Etch and Prime group for SBS resulted in the lowest mean. Adhesive remnant index [ARI] scores indicated that there was more residual adhesive remaining on the teeth in conventional group than in CSE and EP3 groups. In TBP group, the failure sites were similar to those of the acid etching group with ARI 1 but different from those of the CSE group with ARI 2, 3 and 4.

Mayuko Kawasaki,2003[46] studied the effects of using Multibond, a new methyl methacrylate (MMA)-based resin cement with self etching primer, on the shearbond strength of orthodontic brackets compared with Superbond C&B, which is a well-known MMAbased resin cement containing phosphoric acid etching.He concluded that a newly introduced MMA-based resin cement with self-etching primer Multibond has a potential for clinical use in bonding metal or plastic orthodontic brackets to teeth, with the advantage of minimizing the amount of enamel loss and reducing the number of clinical steps during bonding.

Vicente et al (2004) [80] studied to determine if Enhance LC adhesion promoter is material as stated by the manufacturer. (Enhance LC can increase bond strength amongst its own range of bonding products-Light bond) and concluded that there was greater in bond strength for Light Bond/Enhance LC than Transbond XT/Enhance LC. Light Bond (Reliance) system left less adhesive on the enamel than Transbond XT (3M, ESPE), whether or not either of the systems was used with Enhance LC (Reliance). Enhance LC is composed of HEMA (hydroxyl ethyl methacrylate), tetrahydrofurfuryl cyclohexane dimethacrylate and ethanol. The HEMA molecule contains two functional groups, one hydrophobic, the other hydrophilic and works on the concept of Buonocore. The authors also concluded that greater caution is advisable during debonding procedures whenever systems that provide bond strength more than an optimal level and also recommended to avoid in patients with enamel defects.

Goel and Patil (2005)[43] assessed the clinical efficacy of an adhesion booster (Enhance L.C.) on bond failure rates in vivo using split mouth design. They observed an overall bond failure rate of 8.6% and concluded that the application of Enhance L.C. appeared to reduce the bond failure rate when compared with conventional group using Light bond alone.

Vicente et al (2005)[79] compared the effect of a Non Rinse Conditioner [NRC] and the conventional acid etch technique on the shear bond strength and adhesive remnant on the tooth bonded with resin orthodontic adhesive system and concluded that no significant differences were observed in the bond strengths of the two groups evaluated. The amount of adhesive remnant on the tooth after debonding was significantly less when conditioning the enamel with NRC compared with the phosphoric group. This fact is advantageous for orthodontists when removing the adhesive after debonding brackets.

Bishara et al (2005) [8] evaluated the effect of a new integrated bonding system with APC (adhesive precoated brackets) and the conventional acid etch technique with the adhesives applied to the brackets by the clinician. The shear bond strength and total bonding time were evaluated. The results showed significant difference with increased bond strength and decreased bonding time with the new integrated bonding system compared with the phosphoric group.

Saito et al (2005) [71] compared the bonding durability of self-etching primer [Megabond] and conventional acid etching group (65% phosphoric acid gel)using Super-bond C and B resin cement (4-methacryloxyethyl trimellitate anhydride/methyl methacrylate-tri-*n*-butyl borane) before and after thermo cycling tests. They found that there was no significant shear bond strength [SBS] between conventional and self etching primers group before the thermo cycling tests. But after thermocycling tests significant decrease in the SBS was found in the conventional group and no differences were observed in the self-etching primers. The Adhesive remnant index indices were not significant different between the self-etching primers [Megabond] and conventional acid etching group before and after thermocycling tests. Effect of loading mode on bond strength of orthodontic brackets bonded with 2 systems

Thomas R. Katonaa and Robert W. Longb (2006) [75] Did a study to ascertain whether the mode of in-vitro bracket debonding used in a study affects the measured bond strength. Their results showed that when tested in shear-peel mode, traditional etching and priming produced a stronger bond than the single-step self-etch system. When tested in tension, the traditional bond was weaker than the single-step bond, and when tested in torsion, the bond strengths were similar.so they concluded that Bond strength can vary depending on the method of testing. Claims of clinical efficacy might not be valid.

Ismail Amra et al,(2007) compared the bond strengths and to evaluate the debonding site, when a conventional acid-etch conditioner and a self-etching adhesive system Xeno III,used with Transbond XT, composite resin adhesive and concluded that Xeno III can be used to bond orthodontic brackets

Eser Tufekçi et al 2007[27] conducte a study to determine whether there were differences in bond strength between mature and newly erupted teeth when using both conventional and self-etching primer techniques for bonding orthodontic appliances and found that there were no differences in bond strengths between teeth prepared for bonding with self-etching primer and conventional etching techniques, or between teeth with mature and newly erupted enamel

Tancan Uysala 2008[74] tested bond strength and failure site location with bleached and unbleached enamel prepared with Transbond Plus Self-etching Primer between different time intervals and found the use of a carbamide peroxide bleaching agent immediately before bonding significantly reduces the shear bond strength values of self-etching primer systems

Toshiya Endo 2008[76] Compared shear bond strengths of orthodontic brackets bonded to deciduous and permanent teeth bonded with acid etch and self etch bonding systems and found that the shear bond strengths of the brackets bonded to the deciduous teeth with either adhesive system achived clinically sufficient strength of 6 to 8MPa. Whether deciduous or permanent teeth, there were no significant differences in shear bond strength

.the shear bond strength between the acid-etching and self-etching adhesive systems were lower than those to the permanent teeth. Bond failure occurred at the enamel-adhesive interface more frequently in the self-etching adhesive system than in the acid-etching adhesive system.

Leo Lou 2009[42] Found Orthodontic bond failure varies between patients. He conducted a study to see whether chemical composition of the enamel surface might play a role in the variations in bond failure and concluded that the chemical composition was not a significant predictor of in-vitro mean bond strength. Future research should examine the shape of the enamel bonding surface as potentially contributing to the large variances in laboratory bonding studies.

Mariana Marquezan 2010[44] evaluated the shear bond strength of orthodontic brackets bonded to bovine enamel using a new polymerization appliance composed of an LED cluster and compared it with the bond strength obtained using a halogen light for 20 s and conventional LED light for 20 s per tooth.He concluded that there were no significant differences in the bond strengths when using the new Whitening Lase Ortho curing light for 40 s for a half arch compared with conventional halogen and LED curing lights used for 20 s per tooth. This could lead to a potential saving of 60 s curing time per half arch.

Matheus Melo Pithon 2010 [45] et al compared the bond strengths and to evaluated the debonding site using the adhesive remnant index (ARI) provided by a conventional acid-etch conditioner and a new self-etching adhesive system, Xeno IV bonded on One hundred and eighty bovine lower incisors and concluded Xeno IV self-etching adhesive can be used to bond orthodontic brackets in association with Transbond XT composite.The use of Xeno IV optimizes the procedure of bonding orthodontic brackets.

The various materials,strength testing machine employed and the methodology used in this study are listed and briefly described below.

MATERIALS USED IN THIS STUDY

1. **TEETH :-** 120 Sound human adolescent premolar extracted for orthodontic purpose were collected immediately after extraction. The teeth were cleared of soft tissue debris and blood and immediately stored in distilled water which was changed weekly to avoid bacterial growth.

SELECTION CRITERIA FOR TEETH [17]

a) No evidence of caries

b) No developmental defects

c) No cracks due to the pressure during extraction

d) No pretreatment with any chemical agents other than normal saline

2. **BRACKETS :-** Direct bond stainless steel pre- adjusted edgewise, Roth 0.022 slot. premolar brackets with metallic foil –mesh backing (Gemini 3m unitek Monrovia, California) which had a bracket base surface area of about 9.**3** mm ^{2} were used.
3. **ETCHANT :-** 37% Phosphoric acid Scotchbond multi-purpose Etchant (3M unitek).
4. **TWO STEP BONDING AGENT :-** Adper single bond (3M)
5. **SELF ETCH PRIMER :-** Xeno IV (Dentsply)
6. **ADHESIVE :-** Transbond XT (3M unitek, Monrovia, Calif)

7. **LIGHT CURE KIT :-** 3M ESPE Elipar halogen curing light, visible light range 400 to 500 nm, light output power – 450mw/cm2.

8. **OTHER MATERIALS AND ARMAMENTARIUM INCLUDED :**

- Cold cure acrylic
- Alginate moulds for making acrylic blocks into which teeth were fixed
- Distilled water, polishing cup and a slurry of pumice
- Normal saline
- Bracket positioner, Tweezer, Explorer.
- Plastic instruments and spatulas
- Oil free compressed air/water facility for 3 way syringe
- Dental micromotor and airotor unit with hand piece
- Mixing well

9. **UNIVERSAL TESTING MACHINE:**

Tinius Olsen universal testing machine was used for measuring shear and tensile bond strength

METHODOLOGY

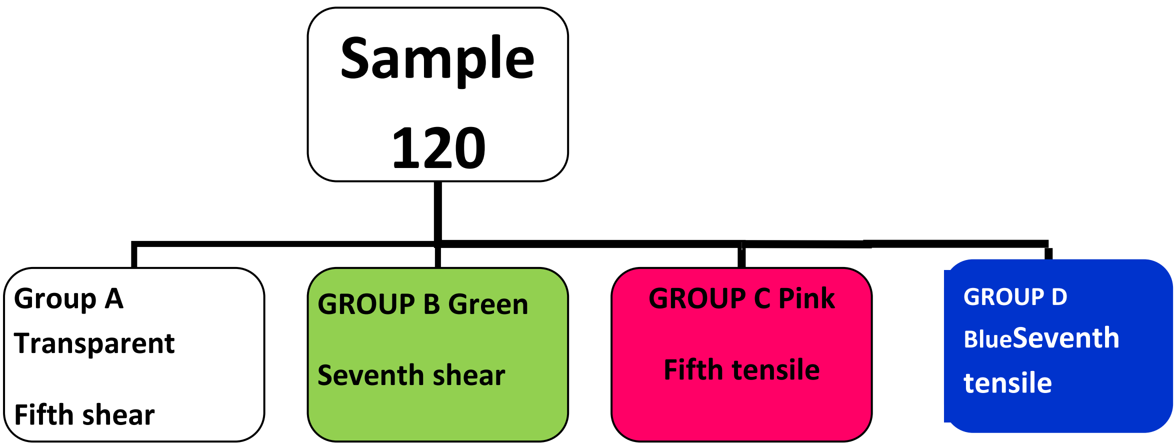
PILOT STUDY

A pilot study was under taken to determine the feasibility of mounting the teeth for testing shear and tensile bond strength, bonding of brackets using single step and two step bonding agents,and debonding force for both shear and tensile was evaluated using the Tinius Oleson universal strength machine.

One hundred and twenty human adolescent premolars extracted for orthodontic purpose were collected from Sri Ramakrishna Dental Collage and Hospital and from some private dental clinic in and around our city. Following the inclusion criteria teeth were selected and were disinfected in 0.1% thymol for 2 weeks and then stored in saline for the rest of the experiment.

DIVISION OF SAMPLES AND SAMPLE PREPARATION

One hundred and twenty premolar teeth were randomly assigned to 4 groups with 30 teeth per group.Each group was given different colour coding(pink, transparent, blue and green).Each tooth from the in vitro sample was mounted on acrylic blocks with roots embedded in a set self cure polymethylmethacrylate resin.



The teeth in Group A and Group B were mounted vertically on the rectangular acrylic block facilitating to test the shear bond strength and teeth in Group C and Group D were mounted horizontally on the rectangular acrylic blocks facilitating to test the tensile bond strength. All the teeth were cleaned with oil – free slurry of pumice in a prophy cup with a slow speed hand piece and were rinsed with compressed air/water 3- way syringe.

BONDING PROCEDURE

Brackets were bonded to the teeth according to the instructions given by the manufacturer. All the bonding procedure were carried out by the same operator.

BONDING PROCEDURE FOR TWO STEP BONDING AGENTS

1. Teeth belonging to the group A and C were bonded using Adper single bond
2. Buccal surface of the teeth of this group were etched with 37% phosphoric acid for 30[62, 17] seconds and rinsed with water spray and dried till it looks frosty white.
3. Single bond bonding agent is then applied and gently air dried after 10 seconds to remove the excess solvent.
4. Bracket were coated with Transbond XT resin and placed on the tooth.The excess adhesive was removed with a scaler.The resin was cured for a period of 40 seconds.

BONDING PROCEDURE FOR SINGLE STEP BONDING AGENT

1. Teeth belonging to the group B and D were bonded using Xeno IV bonding agent
2. The self – etch primer Xeno IV was rubbed on the enamel surface for 15 seconds, then with a gentle stream of air the solvent was removed and uniformly spread into a thin flim and dried.

3. Bracket were coated with Transbond XT resin and placed on the tooth.The excess adhesive was removed with a scaler.The resin was cured for a period of 20 seconds. After bonding all the samples were stored in distilled water at room temperature for 24 hours[17]

PROCEDURE FOR TESTING BOND STRENGTH

The specimen of group A and group B were placed in a mounting jig in the Tinius oleson testing machine in such a way that the bracket base was parallel to the debonding force to test the shear bond strength. A hook[28] fabricated with .019 x .025 stainless wire and fixed to a acrylic block was mounted on the other end of the strength testing machine.

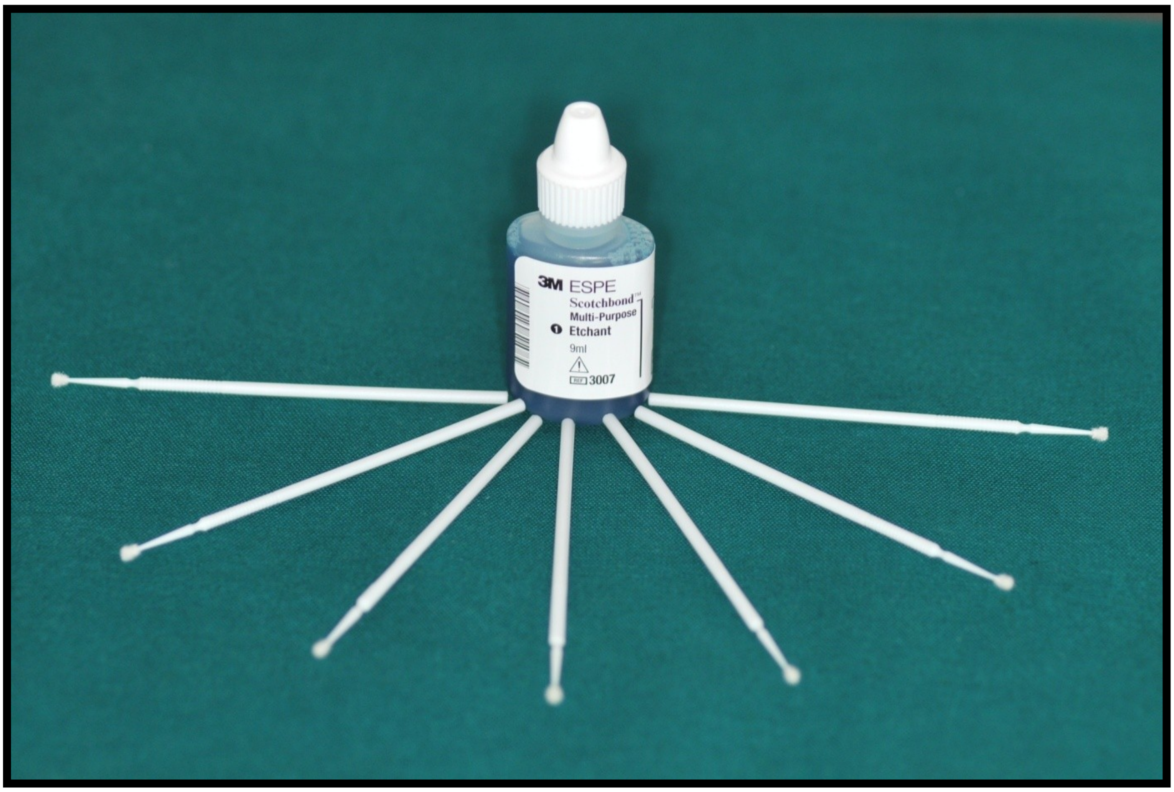
The specimen of group C and group D were placed in such a way that the bracket base was perpendicular to the debonding force to test tensile bond strength. Two hooks fabricated equalling the inter wing distance [32] and fixed to a acrylic block and was mounted on the other end.

A shear and tensile debonding force was applied to the bracket base in a gingivocculusal direction for shear and perpendicular to bracket base at a crosshead speed of 0.5mm/min [(28)] the maximum force necessary to debond or initiate bracket fracture was recorded in Newtons and then converted into Megapascals (MPa) as a ratio of Newtons to bracket base surface area.

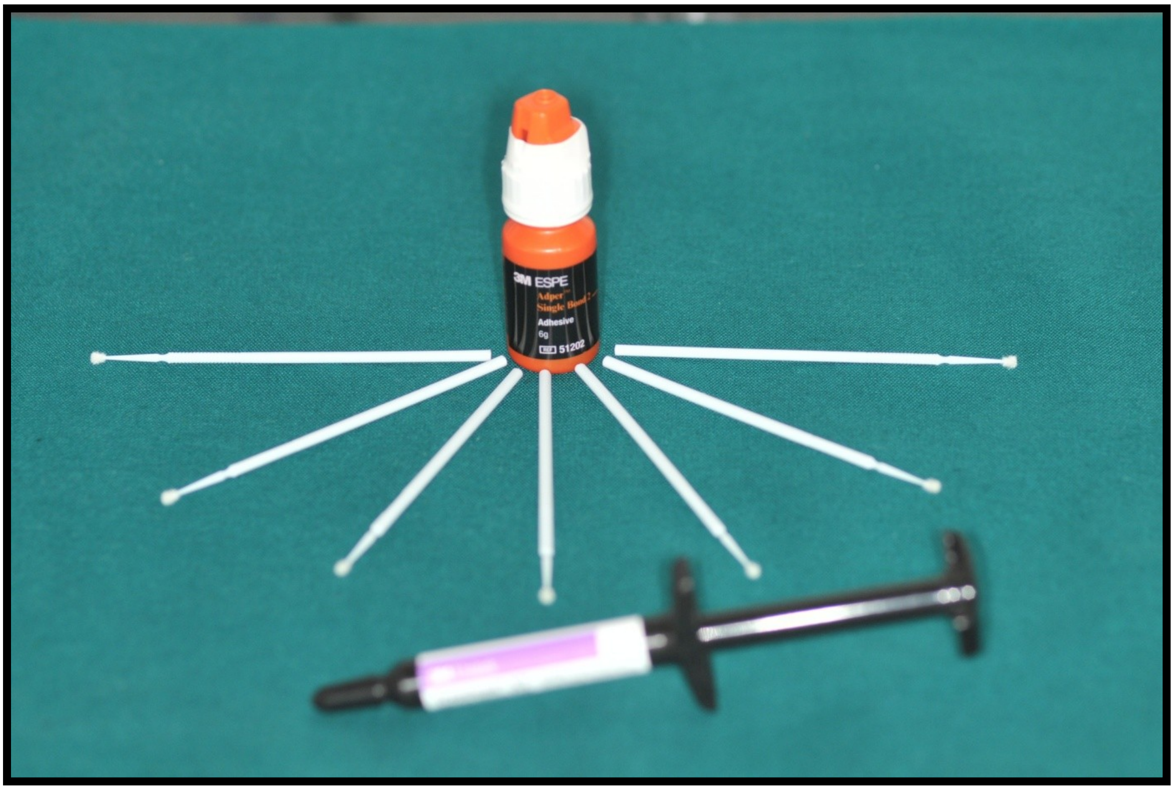
Armamentarium Used in the Study

Light Curing Unit

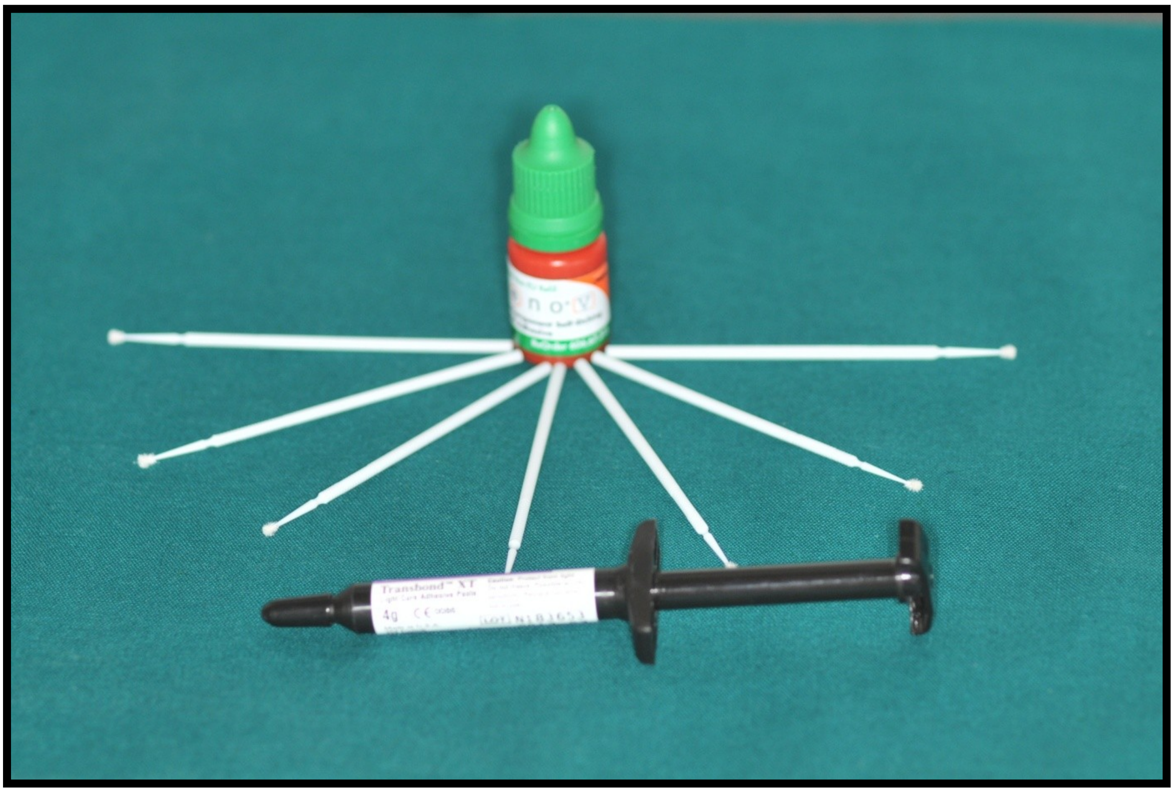
Etchant



Fifth Generation Primer and Transbond Adhesive

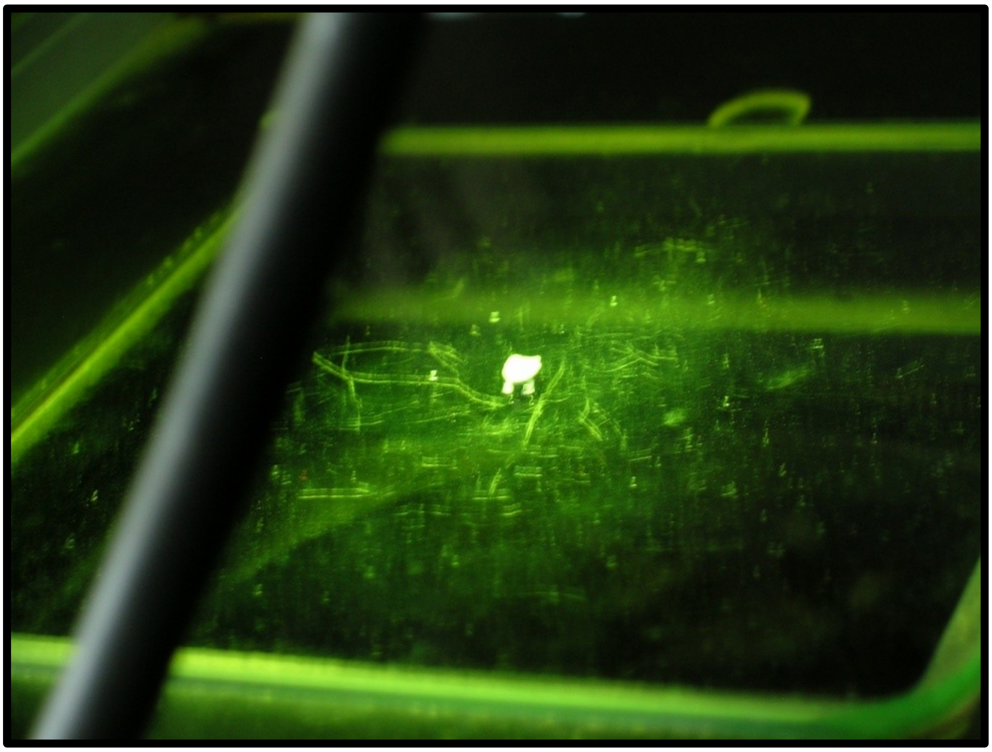


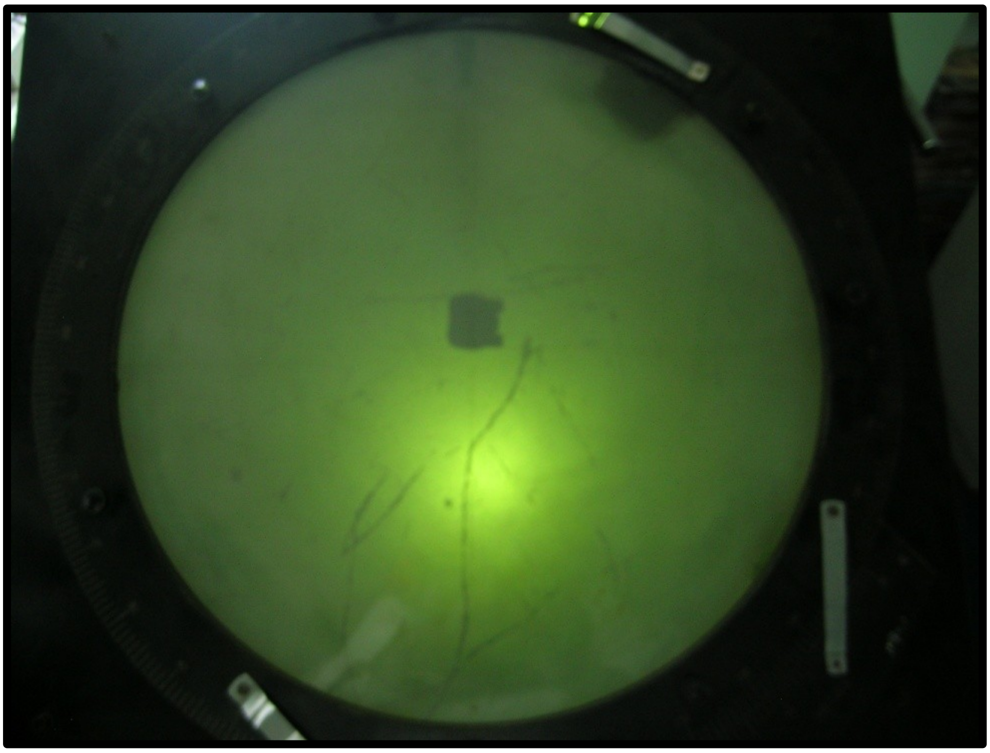
Seventh Generation Primer and Transbond Adhesive



Samples and Hooks

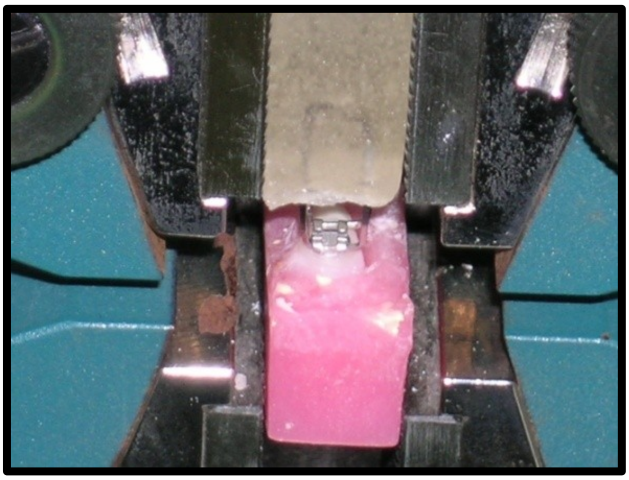
Spectrometer



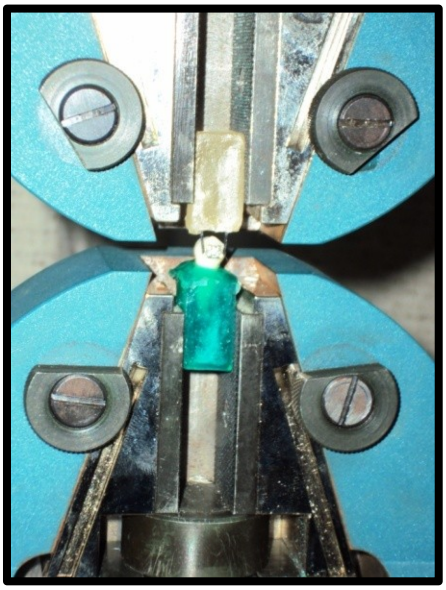


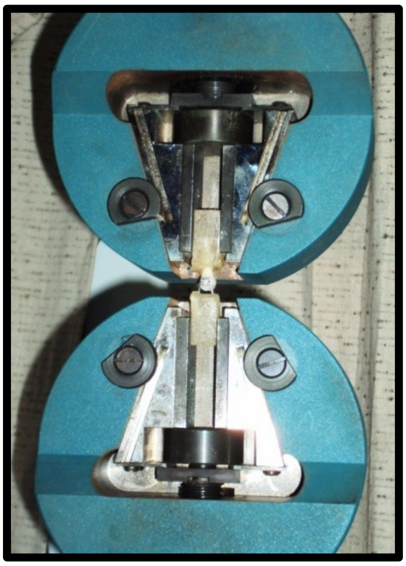
Tinius Olsen Strength Testing Machine

Tensile Bond Strength Testing



Shear Bond Strength Testing





Evaluation of bond strength:-

One hundred and twenty specimens were randomly assigned to one of the 4 groups with 30 specimens in each.Group A and B were tested for shear bond strength and Group C and D were tested for tensile bond strength.

Breaking load at which bond failure occurred was recorded in newtons and the bond strength was calculated by dividing the breaking load with bracket base area which was calculated using a spectrometer and was found to be $9.3mm^2$.

The values obtained were statistically analysed. The descriptive statistics including the mean, standard deviation, standard error mean and 95% Confidence interval for the four group of values were calculated and tabulated.

A Null's hypothesis and an Alternative hypothesis was postulated and either one was accepted after the tests are run and the results were analysed.

The normality of distribution of samples was tested with Kolmogorov –smirnov test and the distribution was found to be normally distributed. Non parametric test was applied and the results showed that the samples were randomly assigned to the groups.

Levene's F test and Independent sample t test were run independently for shear and tensile values to see whether there is any significant difference between variance and mean of the control and experimental group and the results were tabulated.

Table 1 show the kolmogorov- smirnov test values and table 2 shows the non parametric test to ascertain whether the is a random sample. Tables 3 and 4 shows the Leven's F test for significance and table 5 and 6 shows Student t test values.

The mean shear bond strength of conventional 2 steps, etch and bond group was 13.48$\pm$ 2.65 mpa. The mean shear bond strength of single step SEP group was 10.36$\pm$ 1.11 mpa. The Student t Test comparison (.00) and Leven's F Test (.001) indicated that these values were significantly different from each other.

The mean tensile bond strength of conventional 2 step etch and bond group and single step SEP group was 6.66 $\pm$ 1.21 mpa and 4.80 $\pm$ 1.34 Mpa respectively.

Table 1

GROUP			SHEAR	TENSILE
Fifth gen (Control)	N		30	30
	Normal Parameters(a,b)	Mean	13.4853	6.6630
		Std. Deviation	2.65497	1.21457
	Most Extreme Differences	Absolute	.144	.164
		Positive	.144	.094
		Negative	-.061	-.164
	Kolmogorov-Smirnov Z		.791	.901
	Asymp. Sig. (2-tailed)		.558	.392
Seventh Gen (Experimental)	N		30	30
	Normal Parameters(a,b)	Mean	10.3660	4.8018
		Std. Deviation	1.11141	1.34214
	Most Extreme Differences	Absolute	.131	.108
		Positive	.131	.105
		Negative	-.108	-.108
	Kolmogorov-Smirnov Z		.719	.591
	Asymp. Sig. (2-tailed)		.680	.876

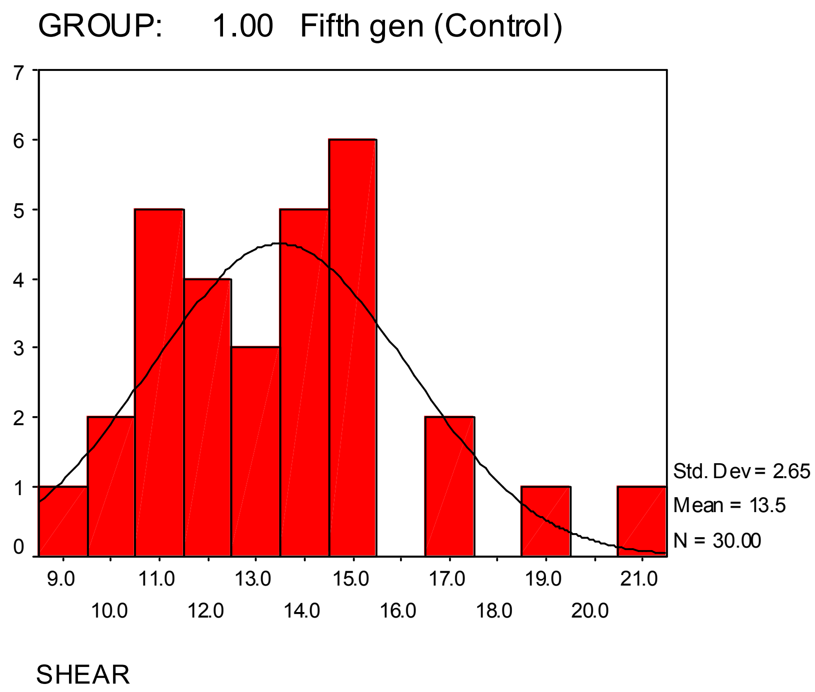
Null hypothesis: The observed data is drawn from the population which follows normal probability distributions.

Alternate hypothesis: Data is not normally distributed.

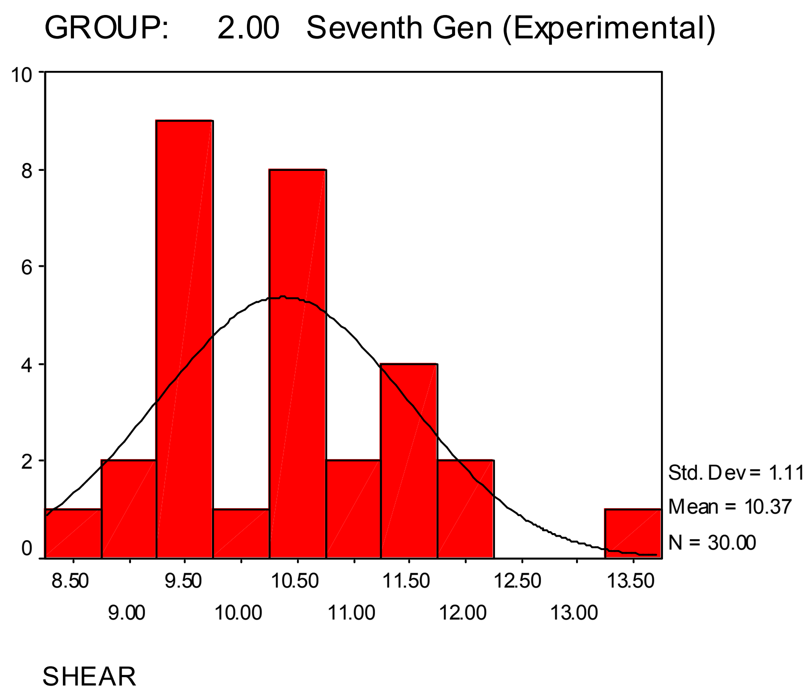
Inference:

From Table 1, since all asymptotic significance values are greater than 0.05 (5% level of significance), the null hypothesis is accepted for all sets of data. It is inferred that the results obtained is normally distributed for all Shear and Tensile with two shot information.

Graph



GROUP: 1.00 Fifth gen (Control)
7
6
5
4
3
2
1
0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
Std. Dev = 2.65
Mean = 13.5
N = 30.00
SHEAR



GROUP: 2.00 Seventh Gen (Experimental)
10
8
6
4
2
0
8.50
9.00
9.50
10.00
10.50
11.00
11.50
12.00
12.50
13.00
13.50
Std. Dev = 1.11
Mean = 10.37
N = 30.00
SHEAR

Graph

Table 2

GROUP		SHEAR	TENSILE
Fifth gen (Control)	Test Value(a)	13.49	6.94
	Cases < Test Value	15	14
	Cases >= Test Value	15	16
	Cases >= Test Value	15	16
	Total Cases	30	30
	Number of Runs	16	10
	Z	.000	-2.028
	Asymp. Sig. (2-tailed)	1.000	.053
Seventh Gen (Experimental)	Test Value(a)	10.33	4.72
	Cases < Test Value	13	13
	Cases >= Test Value	17	17
	Total Cases	30	30
	Number of Runs	18	13
	Z	.669	-.846
	Asymp. Sig. (2-tailed)	.504	.398

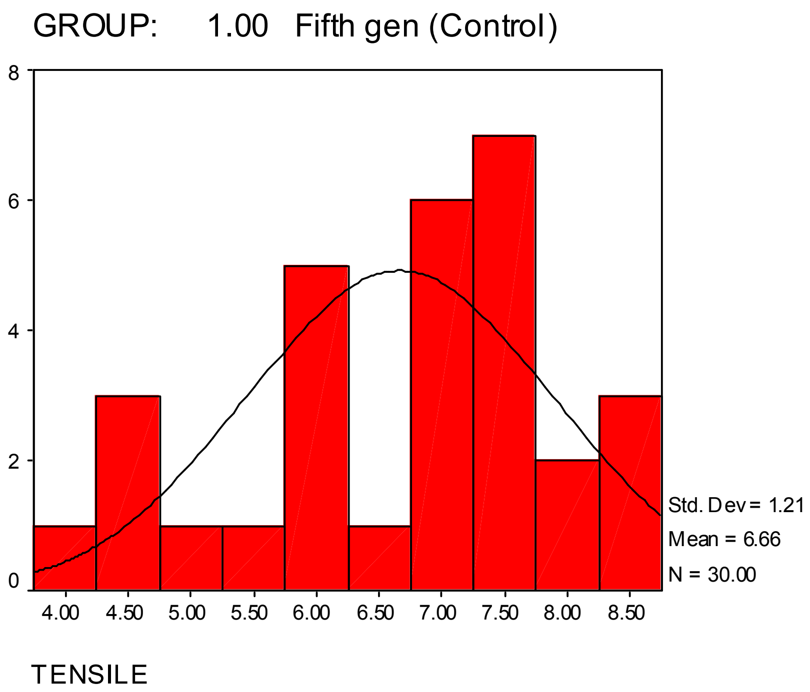
Null hypothesis: The observed data is a random sample.

Alternate hypothesis: Data set is not random.

Inference:

From Table 2, since all asymptotic significance values are greater than 0.05 (5% level of significance), the null hypothesis is accepted for all sets of data. It is inferred that the all sample data sets show randomness

Table 2. Non parametric tests: Runs Test



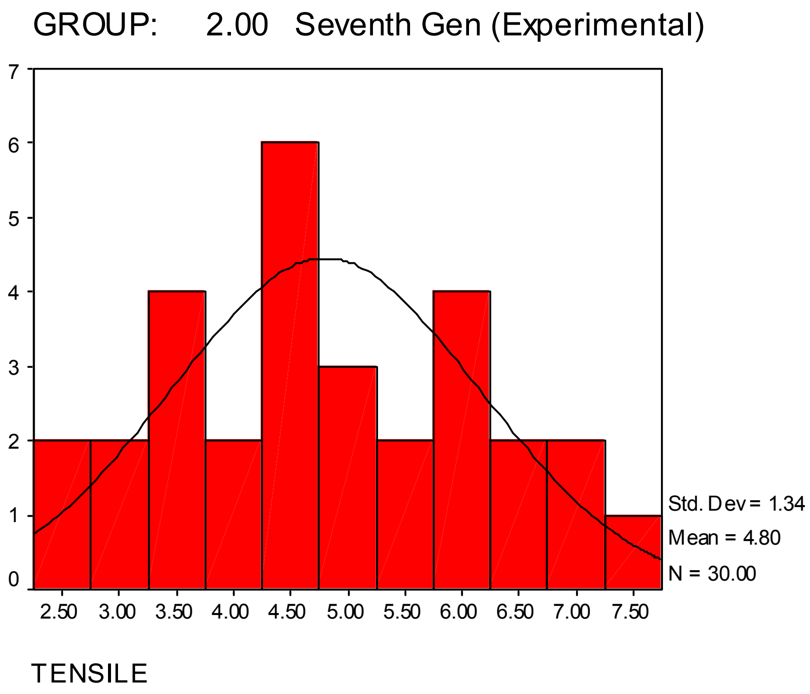


Table 3

	GROUP	N	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval
SHEAR	Fifth gen (Control)	30	13.4853	2.65497	.48473	12.4940 - 14.4767
	Seventh Gen (Experimental)	30	10.3660	1.11141	.20291	9.9510 - 10.7810

Table 3. Levene's F Test and Independent Samples t Test for Shear

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
SHEAR						
	Equal variances assumed	12.416	.001			
Equal variances not assumed			5.936	38.861	.000	

Null hypothesis: There is no significant difference between the **variances in** the scores of fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Alternate hypothesis: There is a significant difference between the **variances in** fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Null hypothesis: There is no significant difference between the **means in** the scores of fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Alternate hypothesis: There is a significant difference between the **means in** fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Inference: From Table 3,

Since significance value in Leven's F test is greater than 0.05 (5% level of significance), the null hypothesis is rejected for data. It is inferred that there is a significant difference between the **variances in** fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Since significance value in student t test is greater than 0.05 (5% level of significance), the null hypothesis is rejected for data. There is a significant difference between the **means in** fifth generation (control group) and seventh generation (experimental group) results of Shear strength.

Interactive Graph

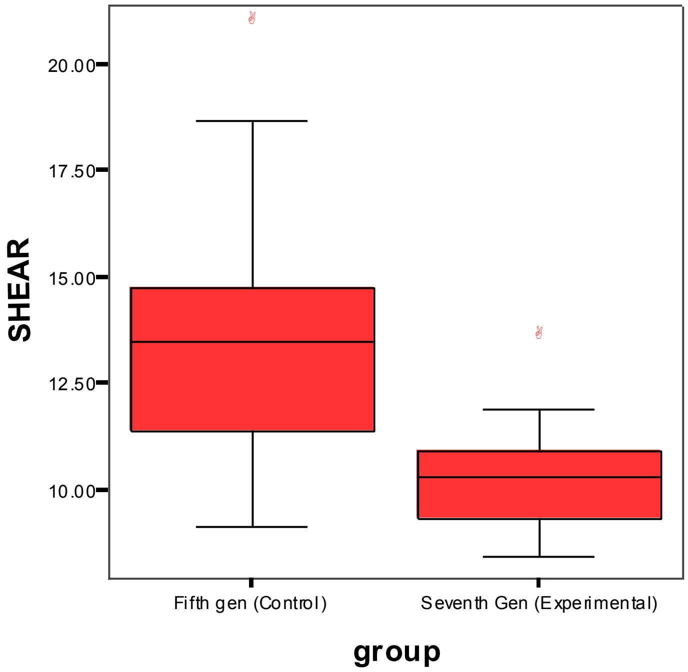


Table 4

	GROUP	N	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval
TENSILE	Fifth gen (Control)	30	6.6630	1.21457	.22175	6.2095 - 7.1166
	Seventh Gen (Experimental)	30	4.8018	1.34214	.24504	4.3006 -5.3030

Table 4. Levene's F Test and Independent Samples t Test for Tensile

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
TENSILE						
Equal variances assumed	.231	.633	5.632	58	.000	

Null hypothesis: There is no significant difference between the fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

Alternate hypothesis: There is a significant difference between the fifth generation (control group) and seventh generation (experimental group) results of Tensile strength

Null hypothesis: There is no significant difference between the **variances in** the scores of fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

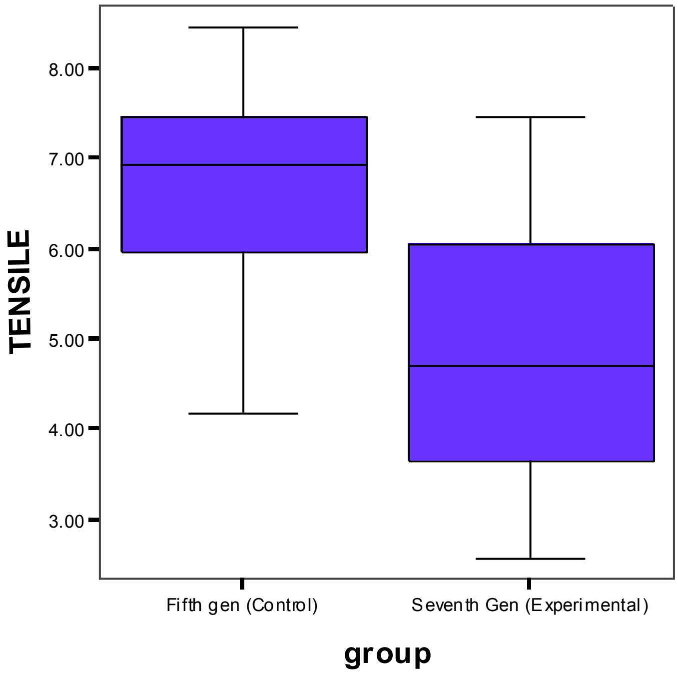
Alternate hypothesis: There is a significant difference between the **variances in** fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

Null hypothesis: There is no significant difference between the **means in** the scores of fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

Alternate hypothesis: There is a significant difference between the **means in** fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

Inference: From Table 4, since significance value in Leven's F test is greater than 0.05 (5% level of significance), the null hypothesis is accepted for data. It is inferred that there is no significant difference between the **variances in** fifth generation (control group) and seventh generation (experimental group) results of Shear strength. Since significance value in student t test is greater than 0.05 (5% level of significance), the null hypothesis is rejected for data. There is a significant difference between the **means in** fifth generation (control group) and seventh generation (experimental group) results of Tensile strength.

Interactive Graph



The direct bonding of orthodontic brackets has revolutionized and advanced the clinical practice of orthodontics. Present day bonding makes use of acid etchants followed by primer materials as an essential part of the bonding procedure in order to allow good wetting and penetration of the sealant that bond the bracket to the enamel surface.[5,77]

Improvements continue through the introduction of new materials. These improvements are aimed at minimizing the enamel loss, reducing the chair side time, simplify the bonding procedure and to make it more predictable.[13,39,50,58]

Dentistry has witnessed introduction of several bonding agents starting with Bowen's first generation through sixth generation of bonding system. The latest entrant is the seventh generation bonding agent. The elimination of steps with this new bonding agent minimizes the probability of contamination because the etchant and the sealant are applied simultaneously without an intermediary step of washing and drying the tooth between applications.

In this study we have compared the bond strength of brackets bonded with seventh generation primer(Xeno IV) that is used commonly in conservative dentistry to that achieved with conventional 2 step etch and bonding system.

In a self- etching primer, the active ingredient is a methacrylated phosphoric acid ester. The phosphoric acid and the methacrylate group are combined into a molecule that etches and primes at the same time. The phosphate group on the methacrylated phosphoric acid ester dissolve the calcium and removes it from the hydroxyapatite. But rather than being rinsed away, the calcium forms a complex with the phosphate group and gets incorporated into the network when the primer polymerizes. Agitating the primer on the tooth surface serves to ensure that fresh primer is transported to the enamel surface. Etching and monomer penetration to the exposed enamel rods are simultaneous. In this manner, the depth of the etch is identical to that of the primer penetration.

Three mechanisms act to stop the etching process. First , the acid groups attached to the etching monomer are neutralized by forming a complex with the calcium from the hydroxiapatite. Second , as the solvent is driven from the primer during the airburst step, the viscosity rises, slowing the transport of acid groups to the enamel interface. Finally, as the primer is light cured and the primer monomers are polymerized transport of acid groups to the interface is stopped (Cinader D et al)[17].

In late 2000, a new SEP, transbond plus self etching primer (3M Unitec, Monrovia, California; TSEP) was developed especially for orthodontic bonding. Transbond plus SEP is a sixth generation adhesive composite.

Compared with phosphoric acid , Transbond SEP produced a uniform and more conservative etch pattern, with regular adhesive penetration and a less aggressive enamel demineralisation [19].The resin tags were shorter than those observed in control group.However, in the context of bond strength , the increase of surface area and the rheological properties of the resin may be more significant than the depth of adhesive penetration.

The use of a SEP would have the advantage of faster and simplified application technique , allowing adequate etching and priming of enamel and dentine in only one step. In addition to saving time, fewer steps in the bonding process might translate into few procedural errors, minimizing technique sensitivity.

Aljubouri [2] et al compared the mean bonding time of light cure composite using a self etching primer and a conventional 2- stage etchant primer system when bonding metal brackets. They found that the bonding time with SEP was significantly less by 59.0 seconds than that in conventional bonding (115.5 vs 170.5 seconds) when direct bonding 30 teeth.The difference between the two bonding approaches averaged approximately 1.97 s/tooth .

Inspite of conservative etch and the lower adhesive penetration patterns , the effectiveness of the SEP has been proven with numerous invitro studies[3.25,40,80] (Aronald RW,Dorminey JC,L armour CJ Aand Turk T).The shear bond strength of SEPs have been found to be superior to those showed by conventional bonding in either humid or dry environments, including the contamination by saliva (Caccifesta [18] Aronald [3] Buyukyilmaz[17],Zeppieri[85]).

But still there is a controversy concerning the use of SEP to etch enamel.Some investigations show that they provide bond strengths comparable with those obtained with acid- etch technique (Aronald[3] et al , Caccifesta[18] et al,Dorminey[25] et al.). Whilst others have observed significantely lower bond strengths. (Bhisara)[10] et al, Yamada[82] et al, Zeppieri [85], Aljupouri[2] et al). Asgari[4] et al evaluated the clinical failure rate of Tranbond plus SEP in comparison with 37% phosphpric acid for bonding orthodontic brackets and found a failure rate of 0.57% in the SEP group vs 4.60% in the conventional acid etch group .

On the other hand , in a 6 month study by Ireland [34] et al ,the percentage of in vivo bond failures was 10.99 % in self etching group(Transbond plus sep) and 4.95 % in conventional acid etch group. Conversely , Buyukyilmaz[17]et al (2003) Found that the use of Transbond SEP provided significantly greater bond strength than Etching the enamel with phosphoric acid. So there exist a controversy concerning the use of sep to etch enamel.

In an attempt to further reduce the chair side time, the number of curing is also reduced to one. Light curing allows additional working time for bracket positioning and is used by many practitioners. However, unlike restorative dentistry, in which the curing light can be applied directly to the surface of the resin to initiate polymerisation, the light in orthodontic use must be applied to the side of the bracket, requiring the light to bounce and reflect through enamel and dentin to initiate the resin polymerization. Studies[83] have indicated that more light is required when curing with transillumination through enamel and dentin. Other studies[84] demonstrated that there is increased bond strength with increased total light exposure. All of these studies indicate that applying direct light to the primer before applying the filled resin and the bracket might be beneficial to bond strength. According to the manufacturers instruction, selfetching primers should be light cured following their application.Following the placement of the bracket with the adhesive, the teeth are then light-cured a second time. However, it has been demonstrated in an earlier study by Ajlouni and Samir E. Bishara[1] that modifying the bonding protocol does not always significantly and adversely influence the shear bond strength(SBS) of orthodontic brackets and found that light curing the acid-etch primer together with the adhesive after placing the orthodontic bracket did not significantly diminish the shear bond strength as compared with light curing the self etch primer and the adhesive separately. By light curing both the self-etch primer and the adhesive simultaneously , the clinician can potentially achieve an additional 10-second reduction in the bonding time for each tooth. While not only saving clinical chair time, reducing the number of light exposures would shorten the bonding procedure and allow less time for contamination, thereby reducing technique sensitivity. So in this study in both control and experimental group light curing was done only once after the adhesive coated bracket was placed .

A new one-bottle seventh generation type of acidic self-etching primer, Megabond (Kuraray Medical), was developed for composite resin restorations. Rieko Yamada[68] et al (a), determine the shear bond strengths of orthodontic brackets bonded with (1) a composite resin adhesive used with 40% phosphoric acid, (2) the same composite resin used with Megabond selfetching primer, (3) a resin-modified glass ionomer cement adhesive used with 10% polyacrylic acid enamel conditioner, and (4) the same resin-modified glass ionomer cement used with Megabond self-etching primer. Megabond self-etching primer gave no significantly different shear bond strength compared with polyacrylic acid etching. But when used with composite resin adhesive,Megabond self-etching primer gave significantly lower shear bond strength than phosphoric acid etching. However, the shear bond strength of orthodontic brackets bonded with composite resin adhesive after Megabond priming was almost the same as that of brackets bonded with resin-modified glass ionomer cement after polyacrylic acid etching.

FE-SEM observation revealed that Megabond self-etching primer produced less dissolution of enamel surface than did phosphoric acid and polyacrylic acid etching. Megabond self-etching primer may be a candidate for bonding orthodontic brackets using the resin-modified glass ionomer cement for minimizing the amount of enamel loss.

However, when used with composite resin adhesive, the use of Megabond self-etching primer resulted in significantly lower bond strength than when using phosphoric acid etching.

In a similar study by Samir E. Bishara they evaluated a newly introduced self-etching adhesive used in restorative dentistry,AdheSE One, whether could provide acceptable SBS when used to bond orthodontic brackets and concluded that the SBS of AdheSE One was significantly lower than that of the control, Transbond Plus. The mean SBS of the brackets bonded using AdheSE One was 3.6 _ 1.3 MPa, and for the brackets bonded using Transbond Plus, this value was 5.9 _ 3.2 MPa. The SBS of a traditional SEP system used for bonding orthodontic brackets had significantly greater SBS than that of AdheSE One, a self-etching system used in restorative dentistry. Bracket failure modes were also different between the two adhesive systems. Bracket failure typically occurs at the weakest link in the adhesive junction; for AdheSE One, the weakest link appears to be at the tooth/adhesive interface.

Xeno IV[45] (Dentsply Caulk, Milford, Massachusetts, USA) is a self-etching adhesive system that is said to demonstrate high performance in terms of self- etching technology by providing a bond to enamel and dentine comparable with those of conventional adhesive systems with phosphoric acid conditioning (Nunes *et al.*, 2009)(d). The unresolved question regarding Xeno IV is whether it is effective in orthodontic bonding.

Matheus Melo Pithon[45] assessed the SBS of orthodontic brackets bonded with Xeno IV to bovine teeth.Contarary to the other two studies mentioned earlier studies results of this study showed that the use of Xeno IV self-etching adhesive associated with Transbond XT composite does not reduce the SBS, thus demonstrating the viability of Xeno IV in bracket bonding.

This study, we therefore undertook which, compared two bonding systems, a conventional system in which the etching, priming, and the adhesive placement on the brackets were done in separate steps during the bonding procedure and a new system (Xeno IV) in which the etching and priming were combined into one single step.

Combining the use of SEP with reduced number of curing significantly reduces chair side time. However, effective bonding is the main objective. So the present study was undertaken to find out whether seventh generation primer when used in combination with Transbond XT adhesive for bonding orthodontic bracket can produce clinically acceptable bond strengths.In the literature mostly shear bond strength values have been published but only fewer articles have evaluated tensile bond strength. So in this study both the shear and tensile bond strength has been evaluated.

The study sample comprised 30 teeth per group in order to minimize any strong divergence from the mean values.According to Fox[29] et al (1994) conclusions regarding in vitro bond strength tests should be considered valid for samples consisting of 20 -30 specimens.

The findings of this study were statistically analysed for normality of distribution and were tested for randomization of samples.The obtained mean values of the shear and tensile group were tested for significance with student t test which indicated that there is a significant difference between the acid etch group and SEP group when tested for both shear and tensile loading.

In all the 4 groups the initial mean bond strength to the virgin tooth was highest with group A (13.48 $\pm$2.65 MPa) followed by group B (10.36 $\pm$1.11), both groups tested for shear bond strength. The mean bond strength values of Group A samples where the highest and was significantly higher than the values of Group B which agrees with most of the studies which states that bond strength values of fifth generation primers are significantly more than that of seventh generation primers. Our results are similar to study done by Aljubouri et al[1] who found significantly lower bond strength values with the self etching primer (Sixth generation bonding agent) than with conventional acid etching technique.

Possible reasons mentioned were the differences in chemical composition and concentration of the etchant between the two systems.The self-etching primer(Sixth generation bonding agent) uses phosphoric acid ester whose concentration is not given in the marketed product literature, whereas the conventional acid etch technique is based on 37% orthophosphoric acid. In addition, the mode of etching was also different (simultaneous etching and priming versus separate etching and priming stages with the conventional acid etch technique).

Contradictory to our results Vicente et al,[79] found no significant differences in the bond strength of the group in etching primer (Sixth generation bonding agent) and the conventional acid etch technique. Their Scanning Electron Microscopy (SEM) observations revealed that the self etching primer (Sixth generation bonding agent) produced a more conservative etch pattern potentially adequate for orthodontic adhesion needs than phosphoric acid.

Bishara et al[16,10] and Buyukyilmaz et al [17] reported higher bond strength values with self etching primers (Sixth generation bonding agent) than with conventional acid etch technique. The authors claimed that the advantage to simultaneous etching and priming was the primer penetrates the entire depth of the etch, ensuring an excellent mechanical interlock as confirmed by their SEM studies.

Contrary to our study there was no significant difference between the bond strength values achieved with two step etch and bond done with transbond XT Primer and adhesive and xeno IV with Transbond XT adhesive in the study done by Matheus Melo Pithon et al.The mean bond strength of both fifth and seventh generation groups where higher ,21.88 Mpa and 20.74 Mpa respectively in the study. This could be because bovine tooth were used instead of Human teeth and the bracket base surface area was 14.2mm which was considerable bigger than the brackets used in this study which was calculatedto be 9.3mm^2.

The mean tensile bond strength values obtained for the fifth generation and seventh generation groups in our study were 6.66$\pm$ 1.21 and 4.80 $\pm$ 1.34 Mpa respectively__which are considerably low and were comparable with the tensile bond strength obtained in a study done by Claudia A .Reichender[80] et al conducted using various bonding systems.

Bond strength levels of 5 to 8 Mpa have been reported to be adequate for bonding orthodontic brackets to teeth[80,64]. According to our findings all measured values are sufficient for orthodontic bonding .Shear forces are the most prevavent during mastication, whereas tensile load occurs less frequently.

In a single – centre randomized controlled clinical trial by N .Manning et al[43] the bond failure rate for acid etch technique and SEP were 7.4 % and 7.0% respectively and was not statistically significant. When operator,patient, and tooth characteristics were analysed ,only the bracket location was found to be significant.Maxillary brackets failed more than the mandibular brackets..

Similarly in a study by Toshiya Endo et al[76] on permanent and deciduous teeth they found no significant differences in shear bond strength between acid – etching and SEP group but found a significantly lower bond strength on deciduous compared to bonding on permanent teeth.

The comparison of bond strength measurements of different studies is difficult and complicated because of the variety of the materials and methods, including variations in tooth type like primary and permanent teeth and individual difference in the enamel make up, timing and concentration of etchant , storage conditions,methods of debonding[72] ,analysis of the results, and the selection of products for comparison. When evaluating other studies we should also note the make and type of brackets and the mesh size and area of the bracket base.

There can be a vast difference between the bond strength values obtained in invitro and invivo bond strength results .Kevin L.Pickett et al [38] in their study have compared the mean values obtained using a strength testing machine , an invivo debonding device used invitro and the invivo debonding deviced used invivo.11.02

Mpa, 12.82 Mpa and 5.47 Mpa were the respective bond strength obtaine which were significantly different from each other , and hence concluded that the invivo bond strength is considerably lower than what is said to be achieved when tested invitro settings. The reason they gave included numerous intraoral factors including saliva,acid,mastticatory forces, variable patient absuse and forces from orthodontic mechanotherapy itself.

Fritz et al[72] suggested a seprate control for each study because SBS can differ significantly depending on the method applied. The favourable In-Vitro bond strength recorded in this study needs to be further investigated by In-vivo studies, and a prospective randomized controlled trial with a split- mouth design and a larger sample size should be undertaken to confirm the suitability of both the adhesives for orthodontic bonding procedures.

This study was conducted to evaluate the bond strength that can be achieved with the newly introduced single bottle, seventh generation primer Xeno IV and to compare it with that achieved with conventional etch and bond ,fifth generation primer, Single bond. Since the brackets bonded to the teeth are subjected to a complex force including shear, tensile and tortional forces, we ,in this study evaluated both shear and tensile bond strength that can be achieved with these primers and to know whether the bond strength achieved with seventh generation primers will be adequate enough, for clinical applications. one other study in which Xeno IV has been evaluated has used bovine teeth, to better simulate the clinical application, we in this study used extracted human premolars.

On the basis of our results it can be concluded that

- The mean shear bond strength of 13.48 $\pm$ 2.6 Mpa for acid etch group is significantly higher than the mean shear bond strength of 10.36 $\pm$ 1.11 Mpa achieved with SEP group .
- Similarly the mean tensile bond strength of 6.66$\pm$ 1.21 Mpa of acid etch group is significantaly higher than the mean tensile bond strength of 4.80 $\pm$ 1.34 Mpa achieved with SEP.
- However all the mean bond strength values were adequate enough to be used for orthodontic bonding.

Though the primers used in this study were commercially marketed for conservative purpose and not exclusively for orthodontic bonding , the bond strength achieved with these bonding agents were comparable with products exclusively marketed for orthodontic purpose.

Reducing the number of clinical steps during orthodontic bonding is a benefit for the clinician and patient by saving time. Additionally, clinicians can reduce the probability of contamination during bonding using single step primers. But the validity of this results needs to be confirmed with in vivo studies and randomised control trial with larger samples on a long term basis.

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